Mixed RP/SP models incorporating interaction effects

Modelling new suburban train services in Cagliari

ELISABETTA CHERCHI[1] & JUAN DE DIOS ORTUZAR[2]

[1] CRiMM - Dipartimento di Ingegneria del Territorio, Università di Cagliari, Piazza d'Armi, 16, 09123 Cagliari, Italia (e-mail: echerchi@unica.it)
[2] Departamento de Ingeniería de Transporte, Pontificia Universidad Católica de Chile, Casilla 306, Cod. 105, Santiago 22, Chile (e-mail: jos@ing.puc.cl)

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Abstract: In order to analyse the impact of a new train service in Cagliari (Italy) a databank including information from a revealed preference (RP) and a stated preference (SP) survey was set up. The RP data concern choice between car, bus and train; the SP data consider the binary choice between a new train service (quicker, more frequent, with a lower fare and more stations than the current one) and the alternative currently chosen by car and bus users. Logit models allowing for correlation among RP alternatives were estimated for this mixed RP/SP data set using the artificial tree structure method. The analysis included level-of-service variables measured with an unusually high level of precision, latent or second order variables (such as comfort), inertia and interaction variables. Different specifications of the utility function were tested, including the expenditure rate model, and the effects of these specifications on modelling results are highlighted. Our results show that for a population mainly composed of fixed income workers, the expenditure rate model is superior to the traditional wage rate model, yielding lower and more significant subjective values of time. Moreover, we found that the non-linear specifications appear to be more suitable as not only better model results were obtained, but also the real distribution of the error terms was revealed (i.e. highlighting correlation among public transport options).

1. Introduction

Sardinia's railway system has always functioned as a suburban service. Because of intense urbanisation over the last few decades, the metropolitan area of Cagliari (where one third of the island's population lives) has grown enormously, to the extent that now the last 20 km of the main railway line actually passes through an urban area. However, since the train service continues to operate as a suburban service, demand in the Assemini-Cagliari corridor has diminished significantly, and today the train is used by just 3% of the population. For this reason, the local rail authority has decided to upgrade the service in this corridor into a metropolitan-like service, increasing not only speed and frequency, but also the number of stations in the last 20 km. This would create a new train system radically different from the existing one. The area under study, to the North of Cagliari, has 20,490 inhabitants and generates about 10,000 trips a day in the corridor of interest. Of these, 75% use car, 20% go by bus, 3% by train and 2% by other modes. On the other hand, 45% of trips are made for work purposes, 20% for study and the remaining 35% for other purposes. Interestingly, more than 80% of the work and other purpose trips are made by car.

In order to analyse the impact of the new system three types of surveys were conducted; a focus group survey to obtain qualitative information on the phenomenon studied and two quantitative surveys; a revealed preference (RP) study to obtain data on the characteristics of trips currently made in the corridor and a stated preference (SP) survey to learn about user preferences for the new train system. Section 2 describes the methodology used to collect the data in detail and the main results obtained. Using the mixed RP/SP approach several models were estimated for different specifications of the utility function (different forms of introducing cost variables and interaction effects). A description of the functional form specification and model structures, as well as the main estimation results are given in section 3. Finally, section 4 summarises our conclusions.

2. Data base construction methodology

To estimate mode choice models for mandatory and discretionary trips nowadays, basically two types of data are used: revealed and stated preference data. The former, based on observations of actual choices, are traditionally used in travel demand modelling. However, they need a large number of observations, may include only existing alternatives and require defining the choice set and calculating level-of-service information for the non-chosen options (many times from aggregate network data). Moreover, variables such as cost and time are often correlated. Further, it has been demonstrated that when RP data are not measured with a high level of precision, model structures and functional forms which would be appropriate with a fully disaggregate (i.e. properly measured) data set may not be selected leading to unknown bias in forecasting (Daly and Ortúzar, 1990).

SP data, designed to overcome most RP problems, allow researchers to have good quality information (since the design is under the analyst's control) and of better value for the survey lire, since many observations can be obtained from each respondent. However, use of SP data may mask a potentially large problem: it is easy to achieve what appears to be good modelling results with almost any SP survey, but if the technique is not used appropriately (for example using a non-customised design in a general context instead of focusing on specific behaviour), serious problems may remain undetected until forecasts are eventually compared with actual outcomes (Ortúzar and Willumsen, 2001).

The recommended approach involves using both data sources jointly, allowing one to exploit their advantages and overcome their limitations (Ben Akiva and Morikawa, 1990; Bradley and Daly, 1997; Louviere *et al*, 2000). In this application, the methodology adopted to collect RP and SP data included three types of surveys. A focus group technique was used to test the RP questionnaire form and some major issues, such as people's attitudes towards trains (especially to changes in the service), people's reactions to questions about income and the best way to introduce the income variable into the questionnaires, in order to improve answer reliability. An RP survey was carried out to obtain data on actual choices and to select a reference trip for using in a customised SP design for each individual. Finally, SP data were collected using the same sample as in the RP survey. Several RP models were estimated to determine relevant parameter values for studying the appropriateness of the SP design with the aid of simulation (see Fowkes and Wardman, 1988). No gifts were offered to the respondents of the RP and SP surveys because, from the focus groups, it emerged that they were genuinely interested in the experience, confident in the organisation that carried out the survey and actually even would judge the offer of a gift as suspicious.

2.1. *RP survey*

In April 1998, a self-completion home interview study was undertaken in which a 24-hour travel diary formed the basis for identifying the RP data. Each respondent filled in the survey forms personally, but all interviews were assisted from the first contact to the end by an interviewer who was also responsible for gathering the socio-economic information. The main steps of the survey methodology were (Cherchi, 1999):

- The sample was randomly drawn from the telephone directory, having verified that 85% of the families living in the corridor had a telephone at home.
- Each member of the family over 12 years of age was asked to participate in a two-part (RP and SP) interview; the interviewer established a date and an adult member of the family (preferably a parent) was chosen to be delivered the questionnaire forms and to complete the first socio-economic part of the survey. This first contact between interviewer and family, together with the telephone contact, proved to be very useful in gaining people’s confidence and clearly reducing the refusal rate. A letter briefly explaining the objectives of the study also accompanied each questionnaire[1].

- On the second visit, for collecting the survey forms, the interviewer also checked these for obvious misunderstandings and lastly asked the personal income of each adult member.
- A detailed check was made immediately after collection and in case of major errors or incomprehensible information, the family was contacted by phone and asked for clarification; this happened in less than 3% of cases.

This technique allowed us to achieve an 83% response rate, with 11% definitive refusals and roughly 6% of families that accepted to participate when first contacted but could not be retraced, even after 15 attempts. It is worth mentioning that the original refusals were 17.5% but after insisting, 37% of these finally accepted to participate. Questionnaires were not difficult but long, since up to 10 trips were described in considerable detail. As the travel diaries were self-completion forms, special care was taken to make them as clear and user-friendly as possible (see Cherchi, 1999) in order to reduce the typical short trip non-reporting bias (i.e. short non-mandatory trips are not mentioned because they are erroneously judged as irrelevant by respondents). A few checks were also made in order to eliminate round off errors (e.g. the arrival and departure times had to be consistent with the sum of the duration of each part of the trip; the name of the road of the bus stop/train station where people waited for the PT service had to exist); these checks allowed us to correct directly 7.7% of the survey forms.

The income variable was the last piece of information asked by the interviewer on the RP survey. Net personal income (NPI) was divided into 10 classes (ranging from no income to an open upper class corresponding to more than 3.5 million lire[2]) and a difficult task was how to define NPI for people like students, who do not earn money but whose life style, and therefore their modal choice, depend on their family's social status. A question was included in the RP survey to evaluate how much money students had to spend, but we found that they did not always have a fixed monthly amount. However, their modal choice varied significantly depending on the family's disposable income. As the survey was directed to all family members it was also possible to calculate family income and hence per capita family income (PCFI); this worked well as a proxy for student's income in all our tests. Since income is a particularly contentious issue in Italy, extra questions were included in order to obtain data regarding people's standard of living to check their answers.

Specific questions were also made to find out whether the person who made the trip was the same who paid for it and chose the mode of transport. Also, a list of non-available alternatives was required including the reason why they were not available; this allowed us to distinguish between objective and subjective availability, and only the first kind was considered. At the end of the day, a sample of 524 people was available for a total of 1,840 trips reported. However, only 40.7% of these trips was in the corridor of interest so the useful starting sample was reduced to 748 observations. After many tests[3] a final sample of 319 individual trips remained for model estimation; roughly reflecting the current structure of demand, 55.3% car users, 40.5% bus users and 4.2% train users (Cherchi, 1999).

2.2 *SP survey*

The main reason for performing an SP experiment was the need to test the introduction of a new train service, radically different from the existing one. With almost the whole population using only two modes, car and bus, we decided to conduct a choice experiment between the new train and the mode actually used. We assumed that, obviously, current train users would also prefer the much improved (in all attributes including the fare[4]) new service.

Given our intention to use RP and SP data jointly, a choice experiment appeared most suitable because: (a) preferences are expressed in a context similar to that of a RP survey; (b) as choices are perceived as more realistic than ratings or rankings, the experiment should also be more understandable to respondents (Ortúzar and Garrido, 1994), and (c) this SP method allows in principle to test any discrete choice model structure (i.e. logit, nested logit, probit).

In spite of the fact that the choice context was quite typical in order to ensure greater realism (and hence reliability) we opted for a customised SP design and put great care in describing, inside and outside the design, the specific trip made by each individual; a map was also added illustrating the zones of origin and destination, and the location of the new stations with particular reference to those that each person could use in her trip. In particular a major effort was devoted to try and diminish one of the most typical negative effects of SP experiments, i.e. that people may not actually act as they state in the experiment. This was a difficult task given the particular situation of the study area. For example, although the corridor inhabitants had been hearing for years about the new train project, it had never materialised. Thus, the positive attitude towards the train that emerged during the focus group survey was surely indicative of this expectation. In fact, although we carried out several pilot tests in order to examine the problem of excessive preferences for the train, in the end, as we discuss in more detail later, a suspiciously large percentage of the sample still stated a preference for rail.

On the basis of the focus group and RP surveys, a set of six variables were singled out as significant for the SP experiment: three time variables (walking, waiting and in-vehicle-time), two cost variables (in-vehicle and parking cost) and a comfort variable. Nevertheless, only four variables were kept in the final design for the following reasons. First, since the railway line was fixed the analyst could not freely modify walking time without departing from the real context; therefore, and because of its importance, we decided to omit this variable from the design and include it as general information. Another variable in this condition was parking time (although this too seemed highly relevant); as many people had free parking at the origin and destination, too many different designs would have been needed to take proper account of this. Parking time was thus included in the car in-vehicle-time variable and a description of parking availability was given outside the design. Figure 1 shows an example of the front page of the SP form, containing the general information presented to current bus users.

Figure 1 approximately here

Depending on the origin-destination of each respondent, the actual mode used and the availability of free parking, different general information was provided in the front pages of the survey forms, for a total of nine different schemes. In particular, the front page for car users was quite similar to that in Figure 1, but with some extra information; for example, in the case of car users with no private parking at destination it included data on traffic and parking conditions, as follows:

IN THE STUDY THE FOLLOWING INFORMATION HAS BEEN TAKEN INTO ACCOUNT:

- Some traffic restriction measures have been envisaged (traffic restricted zones, pedestrian precincts, bus lanes) that can lengthen car journeys and consequently increase travel time and the time to find a parking space.
- An increase in the cost of parking in town as well as the conversion of most on-street parking in town centres to paid parking.
- The cost of fuel and of running a car in general is increasing continuously.

On the other hand, for car users with own parking at the destination, the front page only included information on traffic conditions, as follows:

IN THE STUDY THE FOLLOWING INFORMATION HAS BEEN TAKEN INTO ACCOUNT:

- Some traffic restriction measures have been envisaged (traffic restricted zones, pedestrian precincts, bus lanes) that can lengthen car journeys and consequently increase travel time and the time to find a parking space.
- Urban traffic increases over 15% per year will reduce speeds significantly.
- The cost of fuel and of running a car in general is increasing continuously.

The four variables included in the final design were: trip time, cost, frequency and comfort, each at three levels for the bus users design; and trip time, cost and frequency, each at three levels, and comfort at two levels for the car users design. Various pre-tests and a theoretical analysis were conducted to define the best way to introduce the variable representing the waiting component of a trip in a public transport (PT) system into the design. The major problem was how to describe the real situation experienced by respondents in a case where the bus system has a frequency and the railway has scheduled times. After many tests with different possibilities (see Cherchi, 1999), we adopted the solution of using the frequency variable for both alternatives leaving respondents free to evaluate, on the basis of their own experience, what the proposed bus frequency would really mean in terms of waiting time. It should be recalled that this part of the choice experiment only involved current bus users.

The three levels defined for the comfort variable were: poor, sufficient and good, and were described as follows: “very crowded, you may have to let one bus pass before you can get on”, “bus arrives with space but almost full: you must travel standing”, and “bus arrives almost empty: you can travel seated”. In the bus users design, train comfort was defined in relation to having bus comfort fixed as bad as a reference; in the car users design, car comfort was defined as: “what s/he experiences when driving”, assuming that this would correspond to a high comfort level. Because the car trip comfort was then always “good”, in this case we decided to use only two levels to define train comfort: sufficient and good. The travel cost variable for the new train service was defined as a percentage variation of the revealed cost for the mode currently used. So the variation applied to a season ticket or a one-way ticket for bus users; while for car-users a one-way ticket was considered[5].

As the attribute levels declared by respondent in the RP survey lied in a rather wide range, we decided to use percent variations. For short trip, however, threshold values had to be defined to ensure that people would be able to consider small differences. We also verified that the values of time implicit in the design would cover the range of subjective values of time (SVT) found in the RP data set (as no other study exists for this area). Four pilot tests were carried out to define the better design. Table 1 shows the percentage variations adopted for the final design, while Figure 2 shows an example of the SP cards presented to bus and car users respectively.

Table 1 approximately here

Figure 2 approximately here

A second goal in performing the SP experiment was to include interaction effects and to study their influence on mode choice. Having four variables at three levels allow us to estimate two-term interactions between cost, frequency and travel time, and thus also to account for non-additive effects of the variables in the analysis. Two-term interactions have been said to explain no more than 6% of the data variance against 80% of the main effects (Louviere, 1998). However, the real problem of disregarding interaction effects resides in the potential misrepresentation of the results of mode choice modelling, since important phenomena might not be highlighted. In fact, if relevant interactions are not included main effects could turn out to be biased as they must incorporate somehow the effects of the interaction terms at work; also, interaction terms may dominate main effects implying substantial changes in their parameter values (see Ortúzar *et al.*, 2000). Finally, if interaction terms are not included (and they are relevant) the error term distribution may not satisfy the multinomial logit hypotheses.

In order to estimate three two-term interactions with four variables, the 81 possible combinations involved in a total factorial design were reduced to 27 using a regular fraction design which allowed for the estimation of all the main effects independently of the two-factor interactions, and for the estimation of the three interactions of interest independently between them (see Louviere *et al,* 2000). In the car users design two of the 27 combinations turned out to be the best and worst respectively, so they were eliminated. In order to divide the 25 situations left into three identical blocks another situation, which also dominated most of the remaining situations, was eliminated being careful not to reduce the range of variation allowed for in the design. A block design was also used in the case of the bus users' design leading to only nine situations, a suitable number that a non-trained person can handle without undue stress (see Ortúzar *et al*, 2000, page 160)[6]. Thus, in both cases we used three blocks generated at random without repetition, so that they were complementary; the order of presentation of the 8-9 situations inside each block was also randomised and a second check was made in order to verify that there were no dominant situations.

As stated before, the SP interview involved households in the RP sample, on the basis of their reported trips, and was taken about one year after the RP survey. This unusually long time between the two surveys caused some problems due to changes in the socio-economic situation of some families in the sample (i.e. people who had moved house, got married or bought a car). However, most people remembered the study well and were, in general, still willing to participate. To help people remember the trip they had described in the RP questionnaire (which had been taken as a reference for the SP design), it was described on the front page of the new survey form (i.e. the same page used for the general instructions, see Figure 1).

The SP questionnaires were delivered to each home accompanied by a letter recalling the study and briefly explaining how to complete them. A phone call was made a few days later to collect the completed forms. The number of refusals was small (7.8%) and most people who refused to take part were those who had initially refused to participate in the RP survey but had been recovered as explained above.

The detailed results of the SP survey can be found in Cherchi (1999). Here we will simply discuss in a little more detail the important problem of how to handle the large number of individuals (roughly 43%) that always chose the same option. Apart from the qualitative reasons why this could have happened, a detailed socio-economic analysis was carried out in order to find out whether it was possible to recognise some particular classes of people who always chose the same alternative and, eventually, whether this could influence the estimation results. We found that gender and profession seem to have an influence on this result, since men are less keen to change from car to train (23% of male car users always chose the car, against 14% of women); and the same can be said for employees (41% of car users would always choose the train) versus the self-employed (12% of car users would always choose the train). These results could be explained by the fixed working hours of employees that make the train more attractive. On the other hand, no significant differences were found regarding income and this is a very important result since income plays a key role in our models. Finally, an expected result was that car choice increased with walking time at the origin.

It is interesting to mention that we had only 13% lexicographic[7] respondents (three on trip time and 13 on comfort); this is a very low number in comparison with recently reported experiences (see Ortúzar and Rizzi, 2002; Saelensminde, 2001). We found that the model estimation results did not vary significantly with the inclusion/exclusion of these individuals and for this reason we show only the estimation results for the full sample.

A final sample of 1,077 pseudo-individuals was selected, excluding 772 observations from people who always chose the same option. The modal distribution was as follows: 56% train, 24% car and 20% bus, the sample being equally distributed between car and bus users.

3. Model building and estimation

3.1 *Model specification and variable treatment*

The utility function specification in discrete choice theory results from a series of hypotheses about the mathematical structure of the error terms, the parameters and the attributes. Following the classical formulation of discrete choice models (Domencich and McFadden, 1975) individuals are assumed to choose among several available options associating to each an index of preference (called utility) that depends on the specific characteristics of the alternative (j) and of the individual (q):

$$U_{qj} = U(\underline{X}_{qj}, \varepsilon_{qj}) \tag{1}$$

where $\underline{X}_{qj}$ is a vector of measurable parameters, and ε_{qj} is a random component typically introduced by the modeller due to his/her incapacity to attain perfect information about the individuals. In order to treat utility in discrete choice models the following hypotheses are generally made:

- Additive random term. Random utility can be treated as the sum of the systematic, representative or observable part (V_{qj}), which is a function of the attributes $\underline{X}_{qj}$, and the random component:

  $$U_{qj} = V_{qj} + \varepsilon_{qj} \tag{2}$$

  this hypothesis is generally accepted, and will be maintained in our estimations too.

- Linear-in-the-parameters structure. The systematic utility is usually written as a linear combination of appropriate functions of the relevant variables weighted by unknown parameters $\underline{\theta}$:

  $$V_{qj} = \sum_k \theta_k X_{qjk} \tag{3}$$

  Even if widely accepted and used in practice, this approximation has major consequences in model estimation. Having carried out an SP experiment that allows for interactions, in the next section we will relax this assumption estimating models with non-linear functions and compare them with their linear counterparts.

The variables used in the utility specification include:

Time variables: in-vehicle and walking time (for bus, train and car); waiting time (for the PT modes only), and parking time (for car only). In-vehicle and parking times for the non-chosen alternatives were calculated taking travel time measurements at different times during the day.

For the in-vehicle travel time on the bus service in the corridor, eight measurements were taken and repeated for three successive weekdays making a total of 24 observations. We measured intermediate travel times between one bus stop and the next, as well as the stopping time at each one. One rather interesting finding that emerged from this experience is that the travel time declared by the Assemini to Cagliari bus users (and return) was always slightly (15%) longer than that measured on board. One likely explanation is that, on the one hand, people tend to approximate times (so a journey of 27 min. is rounded off to the nearest five minutes, i.e. 30 min.) and on the other, as the bus is neither comfortable nor reliable there may be a tendency to overestimate travel time, the user feeling that the journey took longer than it actually did.

Walking time was computed directly from the distance walked, based on known (from the RP survey) origin and destination points. For walking time to parking place, depending on each user's final destination, parking availability was checked and average parking time calculated. In the case of the waiting time variable, the same problems highlighted in the SP experiment arose regarding the difference between a frequency service (bus) and a scheduled service (train). For this reason, various specifications were tested but a frequency variable appeared to be more suitable than waiting time and was preferred in the estimation. On the other hand, two different specifications were tested for the parking time variable, either as a distinct variable or as part of travel time; the latter specification giving the best results.

Cost variables: in-vehicle cost (for bus, train and car) and parking (for car only). Since we decided to work with one-way trips, season tickets were reduced to single trips using the number of trips that each type of ticket allowed[8]. The parking cost variable was also tested either as a distinct variable or added to in-vehicle cost in order to create the *ivh* cost variable; the latter specification gave better results. In particular, when car was not the chosen option parking cost was calculated depending on the declared destination and the duration of the activity performed there (also inferred from the RP information), as parking cost varies depending on the zone and length of stay. The public transport fares for the non chosen options were calculated taking into account trip purpose, i.e. for frequent trips (work, study) a season ticket (divided by the number of journeys permitted) was considered and for other purposes a one-way ticket was assumed.

Following the classical microeconomic formulation of Train and McFadden (1978), the best way of introducing cost parameters would be to divide them by the wage rate (WR model), since individuals are supposed to be free to choose how many hours they want to work. An alternative approach, that has appeared to fit the data better in many cases (see Jara-Díaz and Ortúzar, 1989; Ortúzar *et al.*, 2000), is the expenditure rate (ER) formulation proposed by Jara-Díaz and Farah (1987). The ER model derives from the assumption that people who must work a fixed number of hours cannot freely exchange leisure with goods, so what becomes relevant is not how much they earn but how much they can spend in their free time. In order to test the above formulations, the following specifications for the cost variable in the indirect utility function were tried:

WR model $V_{qj} = \theta_c (c_{qj} / \omega_q) + \ldots$ where $\omega_q = I_q / W_q$; (4)

ER model $V_{qj} = \theta_c (c_{qj} / g_q) + \ldots$ where $g_q = I_q / (T - W_q)$ (5)

and where I_q = net income of the q^{th} individual (or per capita income, depending on the specification adopted; we tested both); W_q = hours worked by the q^{th} individual and T = total time available.

Frequency: it is equal to the number of buses/trains that pass in an interval of time (60 min), evaluated around the actual trip time reported by each individual. In the case of transfers a combined frequency formulation that holds for deterministic and Poisson passenger arrivals was tested, but the simple frequency for the first bus taken gave better results.

Comfort: the user was asked to provide a simple judgement of the comfort experienced during the journey described; the variable was pre-coded into three levels: poor, sufficient and good, and two dummy variables were used; *Comf1* equals one if the level of comfort was poor and zero otherwise, and *Comf2* equals one if comfort was sufficient and zero otherwise. The "good" level was left as reference because the comfort variable was only introduced in the PT alternatives (i.e. it was implicitly assumed that the car had high comfort). Therefore, a negative sign for both dummies was expected.

Early/Late: this variable, included for the train alternative alone, was introduced in order to try and capture the differences between a scheduled time system (train), a frequency (bus) and a continuous departure time (car). The variable measures by how many minutes a user must anticipate or postpone her departure time in order to adjust to the scheduled time of the train service. Since the "optimal" departure time (calculated as the difference between the actual time of arrival at the destination and the total travel time by train) varies depending on the individual's departure time, an optimal arrival time at the station of destination (computed as the difference between the current or required arrival time at the final destination and the estimated travel time from the station thereto, typically walking) was defined. Thus, the variable was calculated as the difference between the optimal arrival time at the station of destination and the arrival time of the first available train at the station of origin (Figure 3). A distinction was made regarding the nature of the final destination time; for all travellers who had a fixed entry time at their destination only the early time was considered[9] for all others the minimum time between early and late was used.

Figure 3 approximately here

Interaction variables: as stated before, two-term interactions were also tested in the utility specification of the SP alternatives. Different forms of interactions were tried but, as will be explained in more detail below, the best were those with the following product form:

$$V_{qj} = \theta_{c*tv}(\frac{c_{qj}}{g_q} * tv_{qj}) + \theta_{c*f}(\frac{c_{qj}}{g_q} * f_{qj}) + \theta_{f*tv}(f_{qj} * tv_{qj}) + ... \qquad (7)$$

where tv_{qj} and f_{qj} are respectively the in-vehicle time and frequency experimented by the q^{th} individual using the j^{th} alternative, and $\theta_{c*tv}, \theta_{c*f}, \theta_{f*tv}$ the interactions' unknown parameters.

Finally, it is worth mentioning that we tested an **Inertia** variable in the tradition of Bradley and Daly (1997) but it was clearly not significantly different from zero.

3.2 *Model structure*

Several mixed RP/SP nested logit (NL) structures were tested including allowance for correlation among RP options. As shown in Figure 4, in the most general case[10] two structural parameters have to be estimated: one (ϕ_2) to take into account the different nature of the errors in the RP and SP data sources (scale factor, that does not need to be between zero and one as the RP options are not available to the SP observations and vice versa; see Ortúzar and Willumsen, 2001); the other (ϕ_1) captures the correlation between the PT options and must lie between zero and one (if it is not significantly different from one the NL model collapses to the simpler multinomial logit - MNL - form as the hypothesis of correlation is rejected by the data).

Figure 4 approximately here

The models were estimated using the simultaneous method (Bradley and Daly, 1997) available in ALOGIT[11] (Daly, 1998). The results of several models corresponding to the different functional forms and model structures tested are presented below. It is important to mention that more general forms of combining RP and SP data sets are possible (see the excellent book by Louviere *et al*, 2000).

Tables 2 and 3 show the main results of our analysis. The models presented in Table 2 compare the two micro-economic formulations regarding the effect of working hours on income level. The first two models have a WR specification for the cost variable, the last two the ER specification. Since a wage rate could not be calculated for non-workers[12] (unemployed and retired), in order to make the two formulations perfectly comparable, these observations (82) were eliminated from the sample in these tests.

Table 2 approximately here

Although the parameters in formulations WR and ER have a similar order of magnitude, in general the ER model seems to fit our data better; not only all t-ratios are greater than in the WR model but the ρ^2 index is also bigger. This result was expected since the ER formulation was precisely proposed to simulate mode choice behaviour for people with fixed income and in our sample the self-employed account for only 14%.

It is also interesting to note that both the NL2 structures collapse into the NL1 form suggesting that no correlation would apparently exist between the two PT services modelled. We will come back to this discussion later, since these results, that hold equally for both specifications (WR and ER), appear to depend on other aspects of the utility specification. Note that the scale factor for mixing the RP and SP data sets is not significantly different from one either, suggesting that we could join the data directly with a small premium in terms of efficiency.

How we estimated the walking time variable and the mode-specific constants warrants some comments. For the walking variable, after numerous tests, we decided not to include walking time in the SP car alternative since car users did not perceive this variable which was actually omitted from the experimental design. Regarding the constants, here again after many tests (see Cherchi and Ortúzar, 2001), two different train constants were calibrated for the RP and SP data sets in order to reproduce the market shares for the current and new train services respectively. In particular, since the new train SP constant could not be linked to the RP one, we fixed the RP train constant at the value estimated with the RP data alone to reproduce the market share in the absence of new alternatives, while all other constants were estimated from the mixed model; the generic SP/RP bus constant was left as reference. However, when we incorporated interaction terms both train constants came out almost identical (see model NL4 in Table 3), so we estimated a final model with both constants constrained to have the same value and it gave the best results (model NL5).

Table 3 approximately here

The models in Table 2 and the first model in Table 3 (NL1) were estimated using net personal income (NPI), fixing the income of non-earners in 500,000 liras per month (i.e. a minimum figure), under the assumption that everyone must have a certain amount of money to be able to live. To account for the influence of the family's socio economic status on a person's standard of living, several tests were made using per capita family income (PCFI). The last four columns in Table 3 present models with the ER specification and PCFI, and allow to examine the effect of a non-linear utility specification: the first two models (NL2 and NL3) have a linear form and the other two (NL4 and NL5) include interaction variables. First, note that in all specifications the first order variables are significant (except in a couple of cases for the PT travel time variable) and have the expected sign. The significance of the parameters is higher in the non-linear utility specifications and, contrary to previous findings (Ortúzar *et al.* 2000), the inclusion of the interaction terms did not imply radical changes in the main effect variables.

What is more interesting though, is that the models with non-linear utilities appear significantly superior to their linear counterparts (the likelihood ratio, LR, is always larger than the critical χ^2 value at the 99% level). The cost-frequency interaction is the only insignificant interaction and its omission did not change model quality (see models NL4 and NL5). To take the full main effects into account, we also estimated models including the cost squared variable, which is a test for income effect (see Jara-Díaz and Videla, 1989; Hensher, 1998; Ortúzar and González, 2002), but it turned out to be insignificant.

Our most important finding probably relates to the differences between the NL structures with and without correlation. In the linear specifications (all models in Table 2 and the first three models in Table 3), the NL without correlation (i.e. a MNL for the RP options) appears to be marginally preferable to the NL with correlation, as the structural parameter is not significantly different from one. However, when the hypothesis of linearity is relaxed (models NL4 and NL5 in Table 3), the structural parameter measuring correlation between the train and bus options becomes significantly different from one, and the structure that allows for correlation between the RP alternatives (see Figure 4) fits the data better than the MNL model within each data set. Finally, the t-tests of the scale factor in the last (and best) non-linear model in Table 3 suggest that the variances of both data sets are not the same (which is clearly not the case in the first three linear models). This reinforces our previous finding in the sense that allowing for non-linear effects in the utility specification helps to reveal the real error structure of the data (see also the discussion in Munizaga *et al*, 2000).

4. Conclusions

Quality of data is a decisive issue in model estimation since model results, as well as all the indices derived therefore, are highly sensitive to the type of data used. This is really a crucial problem inasmuch as it is very difficult to recognise poor quality data from the estimation results and to comments honest on theoretical issues judged from modelling results if the data bank is not highly reliable.

Thus gathering information of a high level of quality was an important part of this work and enabled a detailed and precise data bank to be built. In particular, resort to the focus group technique proved especially useful for obtaining qualitative data and allowed us to test people's reactions to certain delicate questions that play a fundamental role in modal choice analysis. One of the most significant issues concerned information about income, as few cases of surveys in Italy are known where this kind of information has been asked directly. On the other hand, we found that the methodology used in the SP survey, halfway between a telephone and a self-completion survey, yielded a high response rate and good quality data, especially in relation to the amount of information requested. Personal contact with the families to gain their confidence and thus to ensure respondents willingness to take part in the survey proved particularly important.

The SP survey conducted on the same sample as the RP survey was favoured by the fact that its design could be adapted to trips actually made by each user, thus ensuring that individuals perceived them as real or feasible. Nonetheless, as seen above, a high percentage of users (in the car user design) always opted for the same mode of transport. Generally speaking this result is not very desirable as it means that either the users may have not evaluated seriously the trade-off proposed in the questionnaire or that there was insufficient variety in the attributes of the design. However, in the case at hand, analysis of the comments that emerged during the focus group survey suggested that the main reason was more psychological than associated directly with the survey design. In fact, it was observed that 20% of car users declared they would always have chosen the train, which is at odds with several studies that have indicated that people are little inclined to change from the private car. Lastly, the greater work involved in incorporating the interaction effects into the SP design was amply compensated by the quality of the theoretical and practical results obtained and the avoidance of the errors in interpreting the results that might be incurred were they are not included.

The major effort we put into designing the survey methodology left us quite confident as to the model results obtained. Confirming the findings of other authors, our results show that the way of introducing the cost variable into the utility function does actually reflect the different ways of acquiring income. For a sample mainly composed of fixed income workers, the expenditure rate model appears superior to the wage rate model (designed for free income workers). This has a major impact, for example, on the subjective values of time (SVT); considering that on average the wage rate in our sample is 1.8 times the expenditure rate, the reader can check that the SVT derived from the expenditure rate model are approximately 50% of those derived from the wage rate model.

Regarding the linear specification hypothesis, frequently used in mode choice modelling, we found that interaction terms significantly improved model results and, what is even more important, they could have a major influence on the error term distribution, highlighting a correlation not revealed by the linear function. This is something that has not been reported before to our knowledge and it would be interesting to learn if further research elsewhere also uncovers this type of finding.

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Tables

Table 1. Attribute levels for the SP choice experiment

Levels	Travel time *(Train - Bus)*	Fare *(Train - Bus)*	Frequency *(Train - Bus)*	Comfort *(Train - Bus)*	
0	-33%	+10%	-50%	=	**Bus users design**
1	-25%	+25%	=	Better	
2	=	+33%	+50%	Much better	
Levels	**Travel time** *(Train - Car)*	**Travel cost** *(Train - Car)*	**Frequency** *(only Train)*	**Comfort** *(only Train)*	**Car users design**
0	-33%	-10%	-50%	Sufficient	
1	-25%	-25%	=	Good	
2	+25%	-30%	+50%	----	

Table 2. Model estimation results: comparing the WR and ER specifications

	WR Models (NPI)		**ER Models** (NPI)	
Attributes	**NL1**	**NL2**	**NL1**	**NL2**
Travel time PT	-0.02568 *(-2.5)*	-0.02147 *(-2.2)*	-0.02872 *(-2.7)*	-0.02316 *(-2.3)*
Travel Time Car	-0.05536 *(-3.0)*	-0.05185 *(-2.6)*	-0.06163 *(-3.6)*	-0.06019 *(-3.4)*
Walking Time	-0.02577 *(-2.0)*	-0.0250 *(-1.7)*	-0.03094 *(-2.4)*	-0.03351 *(-2.3)*
Cost/w (WR models) *Cost/g (ER models)*	-0.002380 *(-0.4)*	-0.002325 *(-0.4)*	-0.004090 *(-1.2)*	-0.004316 *(-1.3)*
Frequency	0.1481 *(2.5)*	0.1387 *(2.0)*	0.1776 *(3.0)*	0.1811 *(2.7)*
Comfort 1	-1.384 *(-3.0)*	-1.236 *(-2.5)*	-1.599 *(-3.8)*	-1.489 *(-3.5)*
Comfort 2	-0.6938 *(-2.7)*	-0.6378 *(-2.3)*	-0.8095 *(-3.3)*	-0.7922 *(-3.0)*
Transfer	-0.4069 *(-1.8)*	-0.4104 *(-1.6)*	-0.4848 *(-2.0)*	-0.5422 *(-2.1)*
Early/Late	-0.2184 *(-3.2)*	-0.2905 *(-3.9)*	-0.2203 *(-3.2)*	-0.3126 *(-4.0)*
Car/licences	2.963 *(7.5)*	3.064 *(7.8)*	3.040 *(7.2)*	3.212 *(7.5)*
K_train (RP)	-1.206	-0.6543	-1.189	-0.4654
K_train (SP)	-0.3201 *(-2.4)*	-0.2493 *(-2.1)*	-0.3185 *(-2.1)*	-0.2044 *(-1.4)*
K_car (RP+SP)	0.0821 *(0.2)*	0.1554 *(0.4)*	0.1576 *(0.4)*	0.3166 *(0.8)*
ϕ_1 *(EMU)*$^{(1)}$	--	1.000	--	1.000
ϕ_2 *(SP factor scale)* *[...]*$^{(1)}$	1.392 *(2.7)* *[0.74]*	1.508 *(2.2)* *[0.73]*	1.171 *(3.3)* *[0.48]*	1.174 *(2.9)* *[0.43]*
L (max)	-712.553	-717.011	-711.861	-718.189
L(C)	-832.442	-849.498	-832.824	-857.841
LR(C)	239.7776	264.9742	241.926	279.3044
$\rho^2(C)$	0.1440	0.1560	0.1452	0.1626
Sample size	1,314	1,314	1,314	1,314

(1) Constrained to be not greater than one.
(*) Where not specified, attributes constrained to be RP/SP generic

Table 3. Model estimation results: testing interactions effect (ER models)

Attributes	NL1 (NPI)	NL2 (PCFI)	NL3 (PCFI)	NL4 (PCFI)	NL5 (PCF1)
Travel time PT	-0.02621 *(-2.5)*	-0.03115 *(-2.7)*	-0.02823 *(-1.7)*	-0.02660 *(-1.4)*	-0.04390 *(-1.8)*
Travel time Car	-0.06717 *(-4.0)*	-0.06842 *(-4.1)*	-0.09291 *(-2.0)*	-0.1722 *(-2.8)*	-0.1963 *(-3.2)*
Walking time	-0.03603 *(-2.8)*	-0.03948 *(-2.8)*	-0.07057 *(-1.7)*	-0.06529 *(-2.4)*	-0.06603 *(-2.6)*
Cost/g	-0.004819 *(-1.5)*	-0.00876 *(-1.8)*	-0.01592 *(-1.6)*	-0.03038 *(-2.6)*	-0.03278 *(-2.9)*
Frequency	0.1857 *(3.3)*	0.2021 *(3.3)*	0.3118 *(2.0)*	0.5198 *(3.1)*	0.5944 *(3.8)*
Comfort 1	-1.757 *(-4.2)*	-1.946 *(-4.2)*	-2.436 *(-2.6)*	-2.690 *(-3.5)*	-3.261 *(-4.0)*
Comfort 2	-0.8994 *(-3.6)*	-0.9789 *(-3.6)*	-1.360 *(-2.3)*	-1.426 *(-3.2)*	-1.608 *(-3.6)*
Transfer	-0.7252 *(-2.8)*	-0.6901 *(-2.7)*	-1.145 *(-1.9)*	-1.237 *(-2.5)*	-1.262 *(-2.5)*
Early/Late (RP)	-0.2211 *(-3.2)*	-0.1948 *(-2.9)*	-0.3079 *(-3.6)*	-0.2317 *(-2.8)*	-0.2203 *(-2.7)*
Car/Licences (RP)	3.203 *(7.4)*	3.205 *(7.2)*	4.938 *(2.0)*	10.26 *(2.8)*	11.38 *(3.2)*
*TravelTime*fare (SP)*	--	--	--	0.001043 *(2.5)*	0.00119 *(2.9)*
*Travel Time*freq (SP)*	--	--	--	-0.009723 *(-2.5)*	-0.01026 *(-3.0)*
*Frequency*fare (SP)*	--	--	--	0.0004157 *(0.8)*	--
K_train (RP)	-1.189 --	-1.427 --	-0.5041 --	-0.5041 --	
K_train (SP)	-0.3028 *(-1.9)*	-0.3472 *(-2.1)*	-0.06014 *(-0.2)*	-0.5509 *(-2.1)*	
K_train (RP+SP)					-0.9868 *(-2.9)*
K_car (RP+SP)	0.1191 *(0.3)*	0.07656 *(0.2)*	0.6397 *(0.8)*	1.854 *(2.0)*	1.624 *(1.8)*
ϕ_1 *(EMU)*(1)	--	--	0.6822 *(0.91)*	0.4465 *(3.04)*	0.4091 *(3.94)*
ϕ_2 *(SP factor scale) [...]*(1)	1.068 *(3.7)* *[0.24]*	0.9771 *(3.7)* *[0.09]*	0.6526 *(2.0)* *[1.09]*	0.6873 *(3.1)* *[1.43]*	0.6179 *(3.8)* *[2.33]*
L(max)	-752.917	-750.613	-757.874	-745.247	-744.322
L(C)	-883.166	-878.153	-908.240	-908.240	-995.077
LR(C)	260.498	255.079	300.7322	325.9856	501.509
$\rho^2(C)$	0.1474	0.1452	0.1655	0.1795	0.2520
Sample size	1,396	1,396	1,396	1,396	1,396

(1) t-t-test with respect to one

(*) Where not specified, attributes are constrained to be RP/SP generic

STATED PREFERENCE SURVEY

Imagine you have to make the same trip that you described in the previous survey:

You described the following trip from:	**Assemini**	to:	**Cagliari**
Starting time from origin: **7:15**		Arrival time at destination:	**8:30**
Starting place: **Via Marconi**		Destination:	**Piazza Dettori**
Purpose: **Study**			

Now assume that the rail service in the corridor Decimo Cagliari has been altered in the following way:

- **5 stations** in Assemini (see attached map)
- **3 stations** in Cagliari (see attached map)
- **1 station** at the Airport
- **1 station** in Decimo (the current one in Piazza Stazione) and **1 station** in Elmas (the current one in Via Arma Azzurra)
- **All train stations** have been **refurbished** and provide a waiting room with seating, bar, newspaper kiosk, facilities for the disabled, etc.
- With **just one ticket**, you can take the train from Assemini to Cagliari and then the bus (all routes) in Cagliari (season tickets are also available).
- **All the train stations** have attended parking where you can leave your car and take the train with a single ticket and, if you want, also board any bus in Cagliari.

To get to the train station you must walk: **7 minutes**

You can interchange from train to bus at: **Citta Mercato**
(*this means that you can get off the train and catch a bus nearby that will take you to your destination just as you do now; see the bus trip described*)

In the following we will illustrate nine situations describing the different options available for travelling between Assemini and Cagliari

Please read them carefully, one at a time and in the order presented, and for each situation indicate in the box provided which of the two modes you would choose to make your trip.

Figure 1 – Example of the front page in the SP experiment for bus users

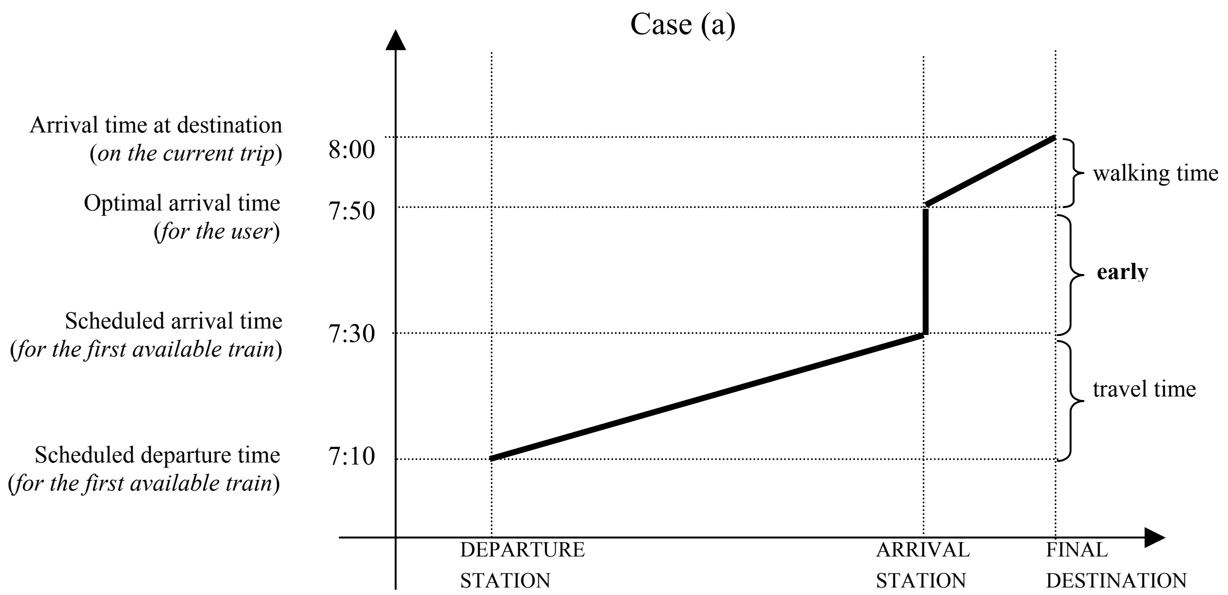
Option No 3

Current Alternative: AUTOBUS No 9	New Alternative: TRAIN
Frequency	**Frequency**
There is a **BUS** every **12** minutes	There is a **TRAIN** every **18** minutes
Travel Time	**Travel Time**
25 minutes from Assemini to Cagliari	**18** minutes from Assemini to Cagliari
Cost	**Cost**
26,000 Liras from Assemini to Caglairi	**33,000** Liras from Assemini to Caglairi
Comfort	**Comfort**
The buses arrive full or with little room. You may have to let buses pass before being able to get on board	*The trains arrive quite empty and you can sit for the whole journey*

Option No 3

Current Alternative: CAR	New Alternative: TRAIN
	Frequency
	There is a **TRAIN** every **15** minutes *(once in Cagliari. the transfer waiting time is a maximum of 1 minute)*
Travel Time	**Travel Time**
Total trip time **26** minutes	Total trip time **20** minutes *(train in the corridor + bus in Cagliari*
Cost	**Cost**
4,000 Liras	**3,600** Liras *(please remember that with the same ticket you can leave your car in the attended parking at the train station, take the train into the corridor and a bus in Cagliari)*
Comfort	**Comfort**
What you experience when travelling	*The trains arrive with enough space but all seats are occupied. You will have to travel standing*

Figure 2 - Example of SP cards presented to bus and to car (with transfer) users.



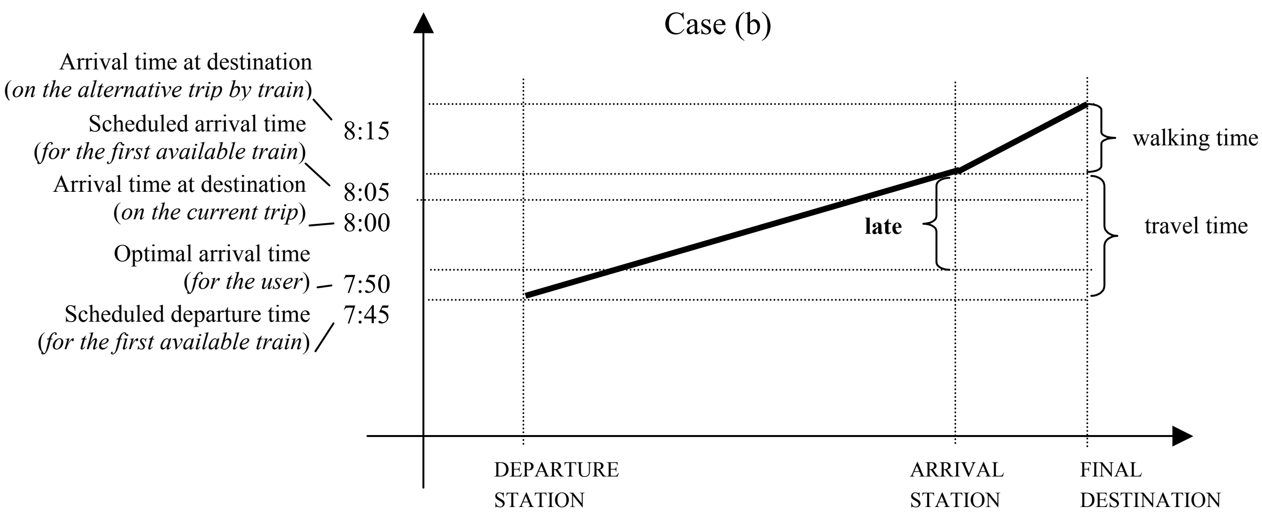


Figure 3. Example of Early/Late calculation

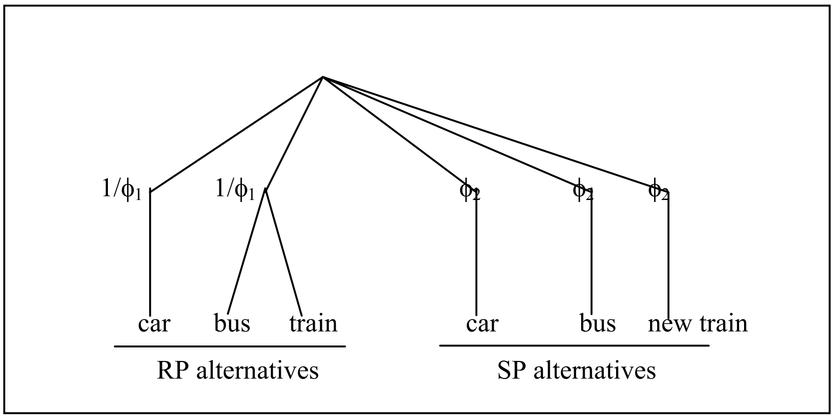


Figure 4. Artificial tree structure for mixed RP/SP data

Notes

1 A second call, 2-3 days afterwards, was made in order to fix an appointment to pick up the questionnaire and in many cases served as a reminder to fill in the form.

2 1US$ was approximately 1,750 lire at the time of the survey.

3 In particular, we excluded all cases for which the alternative chosen was objectively compulsory (43%); this included all chained trips in which all steps (links of the chain) apart from the main one did not have an alternative available (i.e. in that case the complete chain was considered captive to the car mode). This occurred mainly for trips by car made for other purposes.

4 Since the actual train fare is much higher than the cost of other concurrent modes, the levels of variation used in the experimental design were such that the train fare was never higher than what current users actually pay.

5 Bus users who usually purchase a season ticket find it easier to compare transport system on the basis of the cost of the season ticket, even if they have to compare single trips. Car users, on the other hand, find it easier to compare transport systems on the basis of a single trip, even if car use involve other long-term costs.

6 There is no agreement among experts with respect to this issue. In general those devoted to data collection strongly believe that respondent burden – certainly increased by the number of replications – should be kept low in order to ensure good responses (see for example, Ampt, 2001). Modellers, on the other hand, have different views; some strongly believe that this is really not a problem (or that it has not yet been proven, see for example Louviere and Hensher, 2001), and there is at least one research project being proposed to address this issue squarely. However others, apart from us, also show some doubts (see for example, Mazzotta and Opaluch, 1995; Olshavski, 1979; Payne, 1976; Swait and Adamowicz, 1998). In our opinion the issue is at least open and we preferred to be conservative; besides, working with random blocks does not seem to induce problems.

7 Lexicographic respondents are those who appear to choose based on optimising a single attribute (see Saelensminde, 2001 for a good discussion); however, it is in fact not possible to be certain of non-compensatory behaviour in this case, as it is conceivable that very low weights are being applied to the rest of the attributes by these individuals.

8 It must be recognised that people with the same type of ticket could make (and actually made in our sample) a different number of trips to that allowed by the ticket. To take account of this, we also calculated the number of trips made by each individual, multiplying the number of trips made by day (as revealed in the 24-hour travel diary) by the number of days of use; these varied for each individuals depending on the purpose of the trips made and the type of ticket used. However, the results of this specification were slightly inferior.

9 For travellers who needed to arrive at their destination at a fixed time a late time was considered only when the early time was more than 15 minutes ahead and the late time was less than five minutes afterwards, as five minutes were considered a short enough time to recuperate by simply walking faster.

[10] For more details on the use of structural parameters for mixed RP/SP data, the interested readers can check Ortúzar and Willumsen (2001) or Louviere et al. (2000).

[11] Note that since the two data sets (RP and SP) are complementary, to satisfy the *translation invariance* property of the NL model (see Carrasco and Ortúzar, 2002) the inverse of the structural parameter does not require to be included in the SP alternatives.

[12] Note that the expenditure rate (g) can be instead calculated for all categories.